1975
DELTA ORGANIC SOIL SALINITY AND NUTRIENT STATUS STUDY
REPORT OF LABORATORY ANALYSES

University of California
Agricultural Extension

in cooperation with

Central District
Department of Water Resources
State of California

Prepared by:

Jewell Meyer, Area Specialist
Alan Carlton, Soil Specialist

DELTA ORGANIC SOIL SALINITY AND NUTRIENT STATUS STUDY

Third-Year Summary Report and Laboratory Analysis

J. L. Meyer - Alan Carlton*

PURPOSE

This study, which began in 1973, was designed to investigate the salinity status of soils in the Delta. Measurements were made of the soil profile distribution of salts and nutrients and their movement at selected sites in the organic soils of the San Joaquin-Sacramento Delta.

The major crops and the water management practices of the Delta including subirrigation, furrow, sprinkler and flooding were observed.

In 1973, 22 sites were chosen for study on Bacon and Staten Islands; Terminous, Rio Blanco, and Rindge Tracts. During 1974, the number of experimental sites on these islands and tracts were decreased from 22 sites to 8 sites, but an additional site on Sherman Island was included. These 9 were examined in greater detail than in 1973, including sampling and analysis of irrigation water and drainage water.

The 1975 studies utilized six of these sites plus one additonal site to study the relation of the salinity profile in the soil to the salinity of the water below the water table to a depth of 20 feet. The purpose was to see if high salinity profiles could be related to ground waters of higher salinity.

Ground water salinity data were obtained from the Department of Water Resources from their Western Delta Soil Salinity Study, principally upon Sherman Island. It includes salinity measurements of soil water to 80 feet, which was compared with our shallower determinations where conditions warranted.

---

*J.L. Meyer, Area Soil and Water Specialist, UC Cooperative Extension, Modesto. Alan Carlton, Soil Specialist, Agricultural Experiment Station, Parlier.
Robert Mullen and Franz Kegel, Farm Advisors, San Joaquin County, provided valuable assistance with the field work. Laboratory analyses were conducted by Rudy Chavarria and George Gossman, laboratory technicians, San Joaquin County

D-030175

SITES AND HISTORY

Seven sites were used for the 1975 study. The following are a listing of sites, crops, and a brief crop and irrigation history at each location. The sites of 1975 carry the same numbers as in 1973-1974.

SITE	73 CROP	74 CROP	75 CROP	LOCATION	IRRIGATION	CROP HISTORY
2	Asparagus	Asparagus	Asparagus	Terminous Tract	Sprinkled 71-72 Subirrigated 73-74	Corn-70 Barley-69 Tomatoes-68
4	Weeds	Weeds	Weeds	Terminous Y	Nonirrigated	Virgin Peat
5A*	Asparagus	Asparagus	Asparagus	Bacon Is. Near Site 5 (Potato site of 1973-74)	Subirrigated Flooded Winter 73-74	Asparagus (since 1971)
9A*	Corn	Corn	Corn	Terminous Tract	Subirrigated Spud Ditch	Corn-74 Corn-73 Safflower-72 Corn-71 Corn-70
12	Alfalfa	Alfalfa	Alfalfa	Staten Island	Sprinkled since 1968 Flooded 70-71	Beets-67 Wheat-66 Corn-65
13	Corn	Corn	Milo	Rindge Tract	Subirrigated (spud ditch)	Corn-68-64
23	Corn	Corn	Corn	Sherman Island	Furrow	Corn-75 Corn-74 Corn-73 Winter Leached 74-75

*Site 5A was in the same field as the previous site 5, but the sampling location was of necessity moved approximately 100 yards west. Site 9A was moved approximately 20' south of previous site 9.

METHODS

Soil samples were collected at most of the sites at the beginning of the 1975 crop season and after crop harvest. Problems in the field this year prevented our getting all the soil samples which would have been desirable. Samples were obtained at 6-inch intervals from the surface down to the water table or into the water table. Deep suction probes were placed at 10- and 20-feet at the 7 sites to collect ground water samples.

After initial soil samples were obtained at the sites, ground water samples were collected during the summer at the 10- and 20-foot depths. In all cases, these were below the peat and in the mineral substratum.

In addition, the leaching at the Sherman Island site during the 1974-1975 winter season was observed, and water samples of incoming water and leachate (drain ditch water) were taken during the leaching period.

The ground water samples from the extraction tubes were obtained two to four times during the growing season and were analyzed for the same constituents as the soil samples. The nutrient, nitrogen, was analyzed on most of the extracted soil solutions.

Soil and water analyses were determined in the San Joaquin County Cooperative Extension Laboratory. Soil analyses were run on saturation extracts except pH was by saturated soil paste; standard UC Cooperative Extension methods were used. Analyses were for pH, EC, Ca^{++} + Mg^{++}, $CO_3^{=}$, Cl^{-}, NO_3^{-}-N, and HCO_3^{-}. The concentration of the ionic constituents Ca^{++} + Mg^{++} and Cl^{-} are expressed as milli-equivalents/liter (m.e./l.) of the water sample or of the saturation extract (in the case of the soil samples). NO_3^{-}N is expressed as N in parts per million (ppm) of the saturation extract. In the following discussion, the electrical conductivity of saturation extracts from soils are termed EC_e while electrical conductivity of solutions from extraction probes (ground water) are termed EC_{sw}. They are stated in millimhos/cm (mmho).

The values for EC_e and EC_{sw} do not necessarily correlate closely because they measure somewhat different fractions of the soil moisture. These studies are a case in point, and it is not meaningful to directly compare these two analyses in a profile at the same or different times.

RESULTS AND DISCUSSION

The data referred to herein are contained in the appendix attached. These studies continue to indicate that the soil salinity profiles are extremely complex in the Delta. The large number of crops, soils, water, and management schemes are each variables and interact with each other. Evaluation of one variable, water quality as it affects soil salinity, is difficult.

The data collected and analyzed in the 1975 season were found to be consistent with the conclusions in the reports of the 2 previous years. The discussion shown below has reference to the 1975 data. Previous reports should be consulted for background information and conclusions from previous years. Figures 1-11 show the changes in EC_e of the surface soils during the three-year study, for both before the irrigation season (Figures 1, 3, 5, 7, 9) and after the season (Figures 2, 4, 6, 8, 10). For Sherman Island all of the salinity data, EC_e, are shown in Figure 11. Depending upon a given water management, changes or lack of change over the three-year period can be observed in these figures. They show graphically the data presented in the tables and support the discussion below. The following numbered items are observations pertaining to specific sites which can be gleaned from the data.

1. At Site 2, which had been sprinkled for irrigation in 1972-73, salinity has increased in the upper parts of the profile in later years under subirrigation. This is shown by comparing the 1973 and 1975 salinity profiles in Figures 1 and 2.

2. At Site 12, Staten Island, sprinkler plot, there is evidence of summer leaching as well as a general low-salinity profile since sprinkler irrigation has been practiced. This occurs even though the peat is relatively thin (about 3') and rests on a non-sandy mineral substratum which is relatively slowly permeable.
3. At Site 13, Rindge Tract, (subirrigation) there has been very little effective winter leaching. Crop evapotranspiration seems to have caused an increased surface salinity and with little winter leaching; a gradual accumulation of surface salinity has been noted.
4. At Site 23, Sherman Island, winter leaching was very effective. Although furrow irrigation is practiced, surface salinity accumulations similar to subirrigation accumulations were noted. Because of soil cracking, furrow irrigation raises the general water table; surface salinity is, therefore, increased and the results are not unlike subirrigation by spud ditch. However, good winter leaching adequately controlled the surface salinity. Table 2 (or Figure 11 of Appendix) shows the analyses of various inlet and drainage waters during leaching by winter flooding. It was not surprising to find considerably more salt in the various drain waters than in the incoming river water--this was to be expected. What was surprising to us was the high concentration of salts in the surface waters in the leaching fields during the early part of leaching. Apparently not a small amount of salt migrates upward out of the surface layers of soil to the overlying flood waters. If this water is drained off rather than being forced through the soil, better leaching might be expected. Although passage of the leaching waters over and through the

soil increased the leaching water's salinity, it had no appreciable effect on the water's alkaline pH even though the soils were acid.

Deep Suction Probes

At most of the sites where 10- and 20-foot extraction probes were placed, very small gradients in salinity were found between the 2 depths. At 2 sites, extraction probes at 6- or 8-foot depths showed essentially no salinity gradient between the shallow and deeper levels. Wherever a gradient does exist between the 10- and 20-foot levels, the gradient is always negative in the upward direction; that is, the salt concentration is always lower at the 10-foot depth than at the 20-foot. These gradients are shown graphically in Figures 3, 4, 7, 8, 9, 10, and 11 where salinity is expressed by EC. For each depth the average salinity of the several samples taken throughout the season was used as it was found, with one exception, that there was either no or very little change with time. In the few instances applicable, the DWR data from wells 20 feet to 80 feet deep compared with our 10-feet and 20-feet data. There appeared to be no serious conflicts between these two sets of data. The implications of the small negative gradients will be discussed later.

Since there is evidence of an upward hydraulic gradient (the "islands" are below outside river elevations), the ground water is presumed generally to be moving upward. Therefore, the ground water can be a source of salt. However, these waters are not highly saline, but they do vary considerably from one island to another. None of the ground waters would result in soil solution salinity considered harmful to plants of Delta agriculture, but if they were the sole source of water to the crops, the underground waters at Sites 4, 13, and 9 (EC_{sw} of 1.5 and higher) would be expected to require better than normal water management and leaching.

Considering only the 6 sites which were cropped and irrigated (the non-cultivated, weedy, non-irrigated Terminous Site #4 is not considered), that site (Rindge Tract #13) with the highest salinity in the ground waters at 10' and 20' is also the site in which salinity is currently the greatest problem. This is also the site with the lowest EC/Cl^- ratio in the ground waters. It is possible that this is an indication of faster upward movement of these waters at this site. See below for further discussion of the EC/Cl^- ratio in evaluation of the salinity status of these soils.

EC/Cl^- Ratio

The EC/Cl^- ratio has been calculated from the data. It is useful as an indicator of the relative concentrations of the various anions in the salt, particularly sulfate and chloride. It, therefore, can be used as a tracer of various salt sources. Calculations show that sea water when diluted to the concentrations found in Delta ground and soil waters would have an EC/Cl^- ratio of about .13. Solutions with EC/Cl^- above or below this would indicate an admixture with water of a sulfate-to-chloride-ratio differing from sea water. A ratio of less than .13 indicates a water with a smaller ratio of sulfate to chloride than sea water and vice versa. The relatively high EC/Cl^- ratios of the soil extracts indicate a considerably higher sulfate to chloride ratio than either the river waters or ground waters. The question arises as to where these extra sulfates come from. The experiment described below shows the probable source to be the oxidation of the peat soils which results in subsidence.

Peat Oxidation Experiment

The surface level of all the peat islands is presently many feet below sea level even though their initial elevations prior to reclamation were at or slightly above sea level. That process of elevation loss--called subsidence--is still continuing today at a rate of perhaps 2" per year, though the rate varies considerably among islands and on various locations within an island. Although there are many causes for subsidence of peat lands, it is well established that biological oxidation of the organic material is a main contributor. Since plant remains, including peats, contain mineral cations and anions tied up in the organic structure, it seemed reasonable that these mineral constituents would be released as salts when the organic matter was completely oxidized to carbon dioxide and water. After some preliminary work, a single experiment was set up in an attempt to simulate the natural bio-oxidation of peat and to determine what mineral constituents would be released.

A surface soil and the underlying raw peat were chosen and were oxidized in the laboratory with 30% hydrogen peroxide--the mildest chemical oxidant available which would completely oxidize the peat yet do it without the presence of a strong acid which would also dissolve minerals from the silts and clays of the soil. Since only the two samples mentioned (from only one location) were used in the experiment, and since it has not as yet been repeated, the detailed analysis will not be given here. Some interesting results came from it, however, and some useful generalizations can probably be drawn. Neither NH_4^+ nor NO_3^- were analyzed as it was felt that neither of these ions contributed appreciably to soil salinity, either being removed rapidly by crop growth or denitrified to N_2 gas near or at the water table. N is seldom found in large quantities in the soil extracts and is usually very low in drainage waters. Phosphorus was liberated in considerable quantities from the raw subsoil peat, but there were enough heavy metals (Fe, Mn, Cu, Zn) and Ca liberated to precipitate it all. Sulfur was liberated in large quantities, but much of it would be precipitated by released heavy metals. Even so, the unprecipitated balance was sufficient for sulfur (sulfate) to be by far the major anion in the resulting soluble salts. A large amount of

D-030182

acidity appeared to have been formed (biological oxidation of such organic matters result in the formation of acidity too) but only a small amount of chloride was released.

The calculated total soluble salts released per acre per year based on this data depends to a large extent on the soil chemistry assumed and to a smaller extent on such parameters as subsidence rate and soil bulk density. The salts released per year vary from 1072#/year on the basis of the 0-6" sample to 102# to 506#/year for the subsoil peat, depending on the chemistry assumed. We feel that the most likely values will fall between 100# and 400# per acre per year. The EC/Cl^- ratio resulting from the 102# calculation would be 1.7 (6.5% of the anions are chloride). This ratio goes as high as 11 under some assumptions. If one were to dissolve the 102# of salts in an acre-foot of water, one would have a solution of only 33 ppm and an EC of 0.07. However, if such salts became dissolved in only 2 acre-inches of water, the resulting solution would be 225 ppm and have an EC of 0.39. These figures can be compared with the salts left behind by the consumptive use of 2½' of water of 200 ppm salinity which is 1,360 lbs. salt per acre.

It is obvious that this one experiment can't define quantitatively the extent to which the Delta is a source of salts due to subsidence. It is equally clear, however, that due to the phenomenon of subsidence, the Delta peat islands are a source of salts and that under certain circumstances, their contribution might be significant. In other words, it appears likely then that the oxidation-subsidence process in peat soils acts as a salt source, and that an island taken as a whole may be a source rather than a sink for salts. Such implication, however, does not take into account any balance of fertilizers applied onto the island and salts removed in crops. It is clear also where the bulk of the sulfates came from. They came from the decomposition of the peat, and this explains why the EC/Cl^- ratios found either in soil solutions extracted in situ or saturation extracts are higher than either ground or river waters.

Discussion of Ground Water Salinity

Table 3 shows in condensed form the essential data derived from the suction probes at 10' and 20'. The EC values cover a range of more than 10 fold, and the EC/Cl$^-$ ratios show nearly a 3-fold range. Where there are vertical gradients at all, the salt concentration is always greater at the deeper depth, and salts always have a greater ratio of sulfate to chloride (higher EC/Cl$^-$ ratio) at the shallower depth. A close examination of Table 3 reveals that EC, EC gradients, EC/Cl$^-$ and EC/Cl$^-$ gradients appear to be essentially independent of one another. The only exception seems to be a moderate inverse correlation between EC in the 10'-20' zone and the accompanying EC/Cl$^-$. The sites with the two highest salinity concentrations are the sites with the lowest EC/Cl$^-$ ratios and the site with the lowest salinity has the highest EC/Cl$^-$. We have no ready explanation why this should be.

Unless the ground waters are absolutely static and not moving up or down at all, and since there are no functioning plant roots in the 10'-20' zone to remove pure water and concentrate salts therein, then the water must not be moving downward since there is no mechanism for the concentration of salts in this zone. Then we must presume the water is moving upward at some rate. This is the same conclusion one would arrive at from the existing hydraulic gradients as expressed earlier. A salinity concentration gradient will form in the zone where the downward percolating drainage waters mix with the upward moving ground waters of a different concentration. The depth and thickness of this zone would depend on the relative rates of supply from these two sources and the manner in which these waters are eventually drained off horizontally into ditches. It seems reasonable to assume the more rapid the upward movement of ground waters, the thinner and shallower the mixing zone would be. If this is so, then most of the sites show only little evidence of this mixing zone at 10'. On the other hand, if the ground waters are moving upward at a relatively slow rate, diffusion and normal drainage flow lines would carry surface waters deeper and drive the mixing zone to deeper depths. This mixing zone would be detected by gradients of either concentration (EC) or quality (EC/Cl^-).

There are two sites (#5A and #4) which meet these criteria. This line of reasoning would then predict that the upward flow of ground water at these locations would be relatively slow. At neither location is the soil salinity particularly high. Also from this reasoning, one would expect that the greatest hazard from salinity from upward moving ground waters would be from waters of high EC but little or no gradient in both EC and quality (EC/Cl^-). The site with the highest EC in the 10'-20' ground water and little or no concentration and quality gradient is Site #13 on Rindge Tract. This site has currently the most severe salinity problem of any of the sites under study. It would seem likely that the ground waters are at least aggravating this problem. Of the two locations with salinity of the ground waters of about half the Rindge site but with the same small or non-existent gradients, one site (Sherman Site #23) has experienced salinity problems while apparently the other (Terminous Site #9) has not.

Due to the considerable variation in salinity gradients in the shallow ground waters among the islands as well as the quality gradients found among some of them, it appears that the current data indicate that the rate of ground water rise probably varies among the islands, and thus the effect of salt accumulation in surface soils would vary from place to place.

The meaning of these salinity concentrations, gradients, and quality gradients imply something of the <u>rate</u> of ground water rise, but these experiments were not designed to directly measure this. Therefore, only general qualitative statements have been made.

SUMMARY AND CONCLUSIONS

This section will summarize the conclusions from this year's work only. For complete conclusions on the three-year study, the reader should refer also to the 1975 report containing the conclusions of the first two years of the study.

We have previously stated that under a given water and cropping management, the soils tend to acquire a salinity profile unique to that kind of management and that these profiles vary widely in salinity distribution and quantity among the cropping systems found in the Delta. In addition, under a given water management, soil salinity profile changes from the beginning of the cropping (irrigation) season to the end of the season. The salinity at the end of the season may be the same, raised, or lowered depending upon winter water management, but it tends to return to the profile of the previous spring where the management has been constant over a number of years.

Limited analyses of surface and subsoils indicate that subsidence causing oxidation of the organic soils--a process going on in all the organic (peat) soils of the Delta--provides a continuing salt source in these soils, quite apart from any brought to the soil from irrigation and ground waters and concentrated by ET (evapotranspiration). The work so far is not adequate to accurately quantify the amount of salts released, but it is probably between 100# and 400# per acre per year.

The salts released by oxidation of the peat contain large quantities of sulfate with the result that the sulfate-to-chloride ratio of these salts is large compared to the ratio in the ground and irrigation waters.

At the sites studied, unless the ground waters are moving upward fast enough to supply a majority of the water needs to the crops (which seems unlikely) it seems unlikely that the ground waters alone can create a salinity problem in the overlying soils, although they might aggravate an existing one. Due to the considerable variability in salt content of the shallow ground waters in just the seven sites studied, one would be led to suspect, however, that there may be, and probably are, locations in the Delta with shallow ground waters of even higher salinities than those encountered in these studies. There exists, then, the distinct possibility that there may be locations where upward moving saline ground waters are the main cause of surface salinity problems.